BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 06093

SUBJECT: Touchdown Position Deviations Due to LM PGNCS IMU Error Sources - Case 310

DATE: June 24, 1969

FROM: F. LaPiana

ABSTRACT [redacted]

This is an evaluation of the effects of major IMU error sources on LM touchdown accuracy. Using 3σ values of IMU misalignment, gyro drift, and accelerometer scale factor and bias, the RSS values yield dispersion ellipse semi-axes of .37 n.m. downrange and .40 n.m. crossrange. With the effects of 87 minutes of free flight gyro drift included, the RSS values are .37 n.m. downrange and .57 n.m. crossrange. With in-flight accelerometer bias calibration and 87 minutes of free flight gyro drift, the values become .11 n.m. downrange and .45 n.m. crossrange. These system errors are compatible with the present lunar exploration objective of landing within 1 KM of the desired site.

(NASA-CR-106885) TOUCHDOWN POSITION DEVIATIONS DUE TO LM PGNCS IMU ERROR SOURCES (Bellcomm, Inc.) 5 p

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MEMORANDUM FOR FILE

This memorandum presents the effects of the major IMU error sources on LM touchdown accuracy. The trajectory used is the modified two-phase targeting scheme for Mission G[1]. Values used for the error sources were obtained from a presentation to the Apollo Navigation Working Group[2].

The evaluation was performed using the Bellcomm Powered Flight Performance Simulator computer program operated in the statistical mode. In this mode, the nominal trajectory and a trajectory perturbed by a single error source are integrated simultaneously. State vector deviations in position and velocity are calculated as a function of time.

The individual error sources and their magnitudes are presented below. The downrange and crossrange touchdown deviations are based on IMU error sources only, with no position or velocity errors at Powered Descent Initiation (PDI). Using the latest radar noise data[5] a Monte-Carlo analysis showed that when radar noise is superimposed on an IMU error source case, the standard deviation is about 20 feet crossrange and 125 feet downrange. Since this is negligible compared to the deviation caused by major IMU error sources, perfect radar was simulated when the radar data acceptance criteria were met. In the simulation, once radar drop-out occurred, data was not reacquired.

NO POSITION OR VELOCITY ERRORS AT PDI

Error Source		3σ	LM Touchdown Deviations (ft) Downrange	Crossrange
IMU Initial Misalignment				
	X	$\pm.057$ deg.	0	∓1002
	Y	" " "	±80	0
	Z	" " "	0	∓56
Accelerometer Scale Factor				
	X	±300 ppm	0	0
	Y	" " "	0	0
	Z	" " "	∓317	0

Gyro Constant Drift				
	X	±.23 deg/hr.	0	∓190
	Y	" " "	±50	0
	Z	" " "	0	∓44
Accelerometer Bias				
	X	±.0006G	±45	0
	Y	" " "	0	±2220
	Z	" " "	±2216	0

The RSS values for 3σ error sources are 2240 ft. (.37 n.m.) downrange and 2444 ft. (.40 n.m.) crossrange.

With IMU alignment 87 minutes prior to PDI, as currently planned, and a gyro free-flight drift rate of .09 deg/hr., there will be a gyro induced misalignment of .130 deg at PDI. The cumulative effects of free flight and powered flight gyro drift then are:

<u>Gyro Constant Drift</u>
(free flight and powered flight)

	Downrange (ft)	Crossrange (ft.)
X	0	∓2475
Y	±232	0
Z	0	∓172

The RSS values under these conditions are .37 n.m. downrange and .57 n.m. crossrange.

Post-flight data on the IMU shows that with the planned G mission in-flight accelerometer bias calibration, a more realistic 3σ capability estimate is .00015 G instead of .0006 G[3]. When this value is used, the RSS 3σ downrange deviation is .11 n.m. and crossrange is .45 n.m. with in-flight accelerometer bias calibration and 87 minutes of gyro free flight drift.

In summary, systems errors are compatible with the present lunar exploration objective of landing within 1 KM of the desired site. They are the minor contributor to the current 3σ 5.1 by 1.3 n.m. (semi-axis) dispersion ellipse due to navigation and performance errors.[4]

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REFERENCES

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2. Apollo Navigation Working Group Meeting March 21, 1969, Presentation by T. J. Blucker MPAD, Math-Physics.

3. TRW IOC 69:7252.3-66, Apollo Landing Accuracy Data Report for LM Landing Capabilities Study/Investigation, Task AMPO-402, P. C. Smith, 14 March 1969.

4. TRW IOC 69:7252.3-80, Final Report on Review of LM Landing Capabilities Under Study/Investigation Task AMPO-402, P. C. Smith, 31 March 1969.

5. MSC Internal Note No. 69-FM-20, Preliminary Lunar Descent Dispersion Analysis, G. L. Carman and M. N. Montez, 30 January 1969.

BELLCOMM, INC.

Subject: Touchdown Position Deviations Due to LM PGNCS IMU Error Sources

From: F. LaPiana

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